CHAPTER 8

CONSTRUCTION PROCEDURES

The success of streambank protection and stabilization projects hinges on selecting appropriate methods, functional design, and on-site supervision during construction by experienced personnel. Proper installation and quality control is critical to project success. This chapter describes construction procedures and practices for bank stabilization projects to help ensure that project objectives are met.

8.1 GENERAL CONSTRUCTION PLANNING

8.1.1 CONSTRUCTION SUPERVISION

Because many general contractors have little knowledge and experience with vegetative methods, it is important to have experienced personnel on-site for construction management. The basic duty of the construction manager is to ensure that project specifications for handling, preparing and installing plant and other materials are followed, and that the specified structures are constructed as designed. Supervisor(s) should be on site every day to resolve problems with materials, necessary design changes, and other unforseen difficulties. They should also keep detailed records about materials used, costs, work performed daily by each crew, percent project completion, and adherence to schedule. These records provide data on the quantities of material used and work performed, difficulties encountered, and other important information for designing and estimating costs of future projects. Post-project monitoring records should also include cost of and time required for monitoring, replacement of dead plants, and other necessary maintenance.

Qualifications for supervisory personnel should include experience with installing the specified material and structures, including vegetative methods, knowledge of proper handling and planting requirements of the various plant species. To attain project quality control, site supervisors should ensure that the following tasks are completed.

Prior to start of construction:

- Contact the construction superintendent or crew foreman and arrange for a visit of the project site. Discuss each aspect of the project and construction area work limits with contractor. Review erosion and sediment control requirements with contractor.
- Obtain copies of needed plans, permits and easements. All permits must be available for review on the project site.
- Schedule and hold a pre-construction conference with inspectors responsible for permit compliance. All contractors should also attend this meeting.
- Contact and inform property owners in the project area of the upcoming project. Secure construction access where needed.
- Contact a utility location service to identify underground utilities and mark the location in the field.
- Delineate areas within the project site that require special attention.
- Identify vegetation to be preserved on the construction site, and specify preservation methods. Prevent grade changes (either addition or removal of soil) within the driplines of trees to be preserved.
- Erect barriers around areas to be protected, vegetation to be salvaged, and the driplines of trees to be saved to prevent operation of heavy equipment in these areas.
- When vegetative methods are specified, verify location and condition of source sites for harvesting plant materials.
- Arrange for and implement construction staking.

- Ensure that construction materials (e.g., soil, vegetation, rock) meet project specifications.
- Verify that designs match actual ground conditions.

At the start of construction:

- Check the initial site preparation (i.e. grading and shaping) for consistency with the project plans.
- Verify the layout of each specified stabilization method.

During construction:

- Contact regulatory agencies as needed to facilitate required site inspections.
- Coordinate the delivery (timing) of various materials such as rock, vegetation and soil. This material should be delivered in proper amounts and sequence to avoid construction delays or degradation of vegetation.
- Stockpile construction materials in proper amounts and sequence in areas close to the work area. Most construction sites have limited working space and staging areas, most of which may lie at the edge of a streambank. These areas need to be clear for equipment to operate and to avoid construction delays and waste in moving or driving over construction materials.
- Ensure that the location and dimensions of specified excavations are as specified.
- When harvesting, handling and preparing plant materials:
    a. Ensure that fresh cuttings arrive at the project site each day and that unused material is properly stored for use the next day.
    b. Inspect the storage area daily when it is in use to ensure that all unacceptable plant material is removed from the construction site and that only viable materials are installed.
    c. Ensure that invasive plant materials are not brought to the site.
- Ensure correct placement and orientation of cuttings, stakes, and branches in vegetative methods.
- Ensure all materials delivered to the site (soil, plants, rock) are of acceptable quality.
- Ensure that soil compaction occurs according to specification.
- If specified, make sure that fertilizer application and soil conditioning occurs.
- Ensure that necessary staking, pruning and cutting of vegetation occurs as specified.

8.1.2 MINIMIZING SITE DISTURBANCES DURING CONSTRUCTION

In general, the less disturbance to the natural system, the greater the environmental benefits. Thus, disturbance of the stream/river and its riparian corridor should be minimized during construction. Construction damages can be limited by:

- Installing erosion control measures as early as possible to minimize damages from sedimentation.
- Using small equipment and hand labor whenever feasible.
- Limiting site access to as few locations as possible.
- Locating staging areas away from all sensitive areas and their buffers.
- Avoiding construction during critical times such as spawning or nesting periods.
- Minimizing or avoiding extensive grading and earthwork in sensitive areas.
- Retaining natural vegetation whenever possible.
- When vegetation must be removed, limiting the exposure of disturbed soil to the smallest practical area and time.
- For vegetation that will be saved, limiting root exposure to the shortest possible time. Remove and store in a temporary nursery or holding area any existing woody vegetation that might be useful later in the project.
- Stockpiling and protecting topsoil removed during grading operations so that it can be reused.

- Protecting sensitive areas exposed during construction with temporary vegetation and/or mulch.
- Managing runoff and excess groundwater to minimize erosion and slope failure.

8.1.3 SITE PREPARATION

Site preparation are those activities which occur immediately prior to the beginning of project construction. This includes such activities as identifying and visibly marking clearing limits, installing temporary erosion/sedimentation control measures, placing construction fencing around areas to be protected, and installing construction drainage if necessary.

All earthwork activities (i.e., shaping and grading of banks, removal and disposal of excess materials, stockpiling of soil and other activities) should occur in accordance with plan specifications and applicable regulations. Close coordination between the crews installing the erosion and sediment controls and those preforming the earthwork activities is vital for minimizing adverse effects to water quality.

Sites that are wet and poorly drained require extra preparation. At sites with extremely wet soil conditions, it may be necessary to prevent losses of both plants and equipment by providing load-bearing mats from where equipment can be safely operated. If the moisture is from surface water or shallow groundwater, a French drain or other drain may be needed to intercept the flow. In some cases, drains can be incorporated in the structure. A geotechnical expert should be consulted if drainage problems exist.

If needed, the physical properties of the soil can sometimes be altered by adding organic material such as commercial compost, sand, silt, or clay and mechanical mixing. Adding sand to wet clay soils can be extremely difficult as the clay portions often stick together rather than mixing. Although frequently recommended, this process is seldom successful in improving soil conditions.

8.1.4 LABOR NEEDS

Vegetative stabilization methods are often labor intensive. Two crews are needed for most medium to large projects: one for harvesting plant materials and one for installation. The number of crew members will vary with the project. Two people per crew is generally adequate for small projects. On small projects or where the plant material is close by, one crew can both harvest and install plant material as work progresses. On larger projects, crews should coordinate closely to prevent having excess material on site which may result in installation delays.

Unskilled labor can be used if supervised by an experienced crew leader. Because training requirements are minimal, training can usually be accomplished on site in a few days. Some methods, such as constructing fascines, can be completed by individuals who are physically or developmentally challenged, thus providing employment opportunities for these diverse groups. Local and state conservation corps may also be a source of labor. Chamberlain (1986) reported excellent success in revegetation projects along the Cedar River using labor recruited through the Washington State Conservation Corps. The Washington State Departments of Natural Resources and Fisheries have used correctional inmates on some projects (L. Cowan, Wash. Dept. Fish., per. comm., 1992).

8.2 CONSTRUCTION PLANNING FOR VEGETATIVE METHODS

8.2.1 ACQUISITION OF PLANT MATERIAL

Live Cuttings

Live cuttings are normally collected from existing, healthy, native vegetation. Local native plants are generally resistant to disease and are better adapted to local conditions than plants from distant sources. Careful observations of donor material are required to prevent the introduction of

Table 8.1 Relative volume of plant cuttings required for various vegetative methods.

VEGETATIVE SYSTEM	VOLUME OF MATERIAL REQUIRED
Cuttings (Slips)	Small
Rooted Cuttings	Small
Fascines	Moderate
Live Cribwall	Moderate
Live Staking	Moderate to Large
Brush Layer	Very Large
Brush Mattress	Very Large

insect infested cuttings into the project area. The willow bore (*Cryptorhynchus lapathi*), for example, is endemic in northwest willows. This insect bores into the heartwood of the willow, killing the plant.

Plant material may be found anywhere from a few feet to upwards of 50 miles from the project site. Naturally, the further the harvesting source is from the project site, the more costly the operation. Longer hauling distances will also require more project coordination. Advanced planning may provide a suitable plant source near the project site, reducing collection costs as well as transport time and plant mortality between source and project.

Local regulations on collecting plant materials should be reviewed before harvest operations begin. Some regulations, such as the King County Sensitive Areas Ordinance, restrict the collection of plant material from riparian buffer zones and other sensitive areas. Several alternative sites may be needed to obtain the necessary quantities of material.

The source site must contain plant species that will propagate easily from cuttings. For best results, woody vegetation should consist of several different species. It is important to properly identify the species of woody vegetation that is to be used to ensure that adequate amounts of material will be available. Dickerson (1992) describes relative volumes of material needed for some vegetative methods (Table 8.1).

Effective searches for suitable sources of materials can be completed from the air by someone familiar with the area and with local plants. Utility maintenance crews also frequently know where large stands of suitable plants can be found. For projects such as brush mattresses or fascines, storm water retention/detention ponds, utility rights-of-way, or similar managed areas may provide large amounts of vegetation at little or no cost as the vegetation at these sites is periodically cut and removed by maintenance crews.

Because a harvest site may be needed again for future projects, it should be managed carefully and left as healthy, clean, and tidy as possible. Large, unused material may be cut into manageable lengths for firewood, left in piles for wildlife cover, or scattered around for ground cover and to promote decomposition. Unused material should not be left in a condition that could encourage fires or create other safety concerns. Diseased plant material should be destroyed by burning.

Equipment that will result in the cleanest cut (chainsaws, brush saws, bush axes, loppers, and pruners) are recommended for cutting living plant material. Vegetation should be cut cleanly at a 40 to 50 degree angle, eight to ten inches above the ground if the whole plant is being used. This assures that the source sites will regenerate rapidly and in a healthy manner. At some sites such as detention ponds, the entire site may be cut. At other sites, cutting must be done with care to prevent serious degradation or environmental damage of the harvest site.

Rooted stock

Nursery stock should be ordered well in advance of planting dates to ensure sufficient quantity and quality of the desired species. Because there is still a relatively small demand for native plant stock, only limited stock is available each year. For large projects with sufficient lead time, contract growing can eliminate this problem by starting cuttings and seeds anywhere from a few weeks to several months or even years in advance.

If the desired plant species are not available, carefully review plant substitutions suggested by nursery staff. The definition of "native plant" varies widely among horticulture, landscaping, and nursery professionals. Often, nursery stock includes species that simply grow well in the region or is related to the specified native species.

There are numerous commercial sources of plants and plant information. Infonet (1992) produces a monthly listing of stock availability, prices, and size for many nurseries in the Pacific Northwest. Shank (1991) provides a list of Pacific Northwest nurseries that produce native species. Baumgartner et al. (1991) provide information on sources, selection, planting, and care of trees. Table 8.2 lists local growers of native plants. Ideally, the best nursery stock for river projects is from local nurseries, i.e., those located within the same major drainage basin as the project site.

8.2.2 FACTORS AFFECTING PLANT COSTS

The cost of plant material reflects the time and effort required to produce the plant. As such, small plants are usually less expensive than larger plants of the same species. Fast-growing, easily propagated, relatively pest-free species tend to be less expensive and more readily available. Because the cost per plant increases with small production quantities, even an easily propagated species can be expensive if there is limited demand.

Some nurseries may offer discounts for large orders or contract-produced material on a case-by-case basis. Contract growing is recommended if large amounts of rooted stock will be needed, as it allows ample time to produce good quality stock.

The commercial availability of rooted stock varies seasonally as do the species and manner in which they are available. During the winter months, bare-root, single-tubed or balled and burlapped plants are generally available and less expensive. After April, most nurseries put plants into containers, though some nurseries will provide field plants on demand.

The choice of stock type used (balled and burlapped, bare root, containerized, cuttings or live stakes, rooted cuttings, seed mixes) will be defined by the anticipated site conditions. These include river characteristics (e.g., frequency and duration of inundation), soil conditions, control of competing vegetation, and the type of structure to be installed. If competition from grasses or shrubs may be a problem, larger plants or cuttings should be used.

The quality of the plant material is very important for long-term survival. If possible, order plants grown from seed collected from the same geographic area and elevation as the planting site. Most growers have this information available. Often, these plants will be better adapted to climatic conditions of the site than plants from more distant regions.

8.2.3 INSTALLATION TIMING FOR VEGETATIVE METHODS

For maximum success, streambank stabilization projects should be installed while plants are dormant (Schiechtl 1980; Adams 1982; Baumgartner et al. 1991). Once buds break and leaves begin to expand, plant survival rates decrease markedly. Fully-leafed plants may have survival rates of five to ten percent or less. Installations should coincide with cool, moist but not excessively wet weather in either spring (late February to April) or fall (October to mid-December). If high flows are not anticipated against a reconstructed bank, fall is the best time to plant because substantial root growth can occur during the winter. Because root growth occurs any time the soil is not frozen, fall planting allows trees, shrubs, and cuttings to establish better root methods prior to summer droughts than does spring planting. Spring plantings with supplemental irrigation are recommended if site conditions are such that a fall installation may be removed by high flows. Unless irrigation is provided, summer installations can be difficult because of drought stresses that occur when plants are cut or transplanted. While acceptable, winter is generally not preferred because of the difficulty in working wet soil and also because of excessive soil compaction can occur.

While vegetative methods are most effective when installed during late fall to early spring, this may not coincide with the construction window for working in King County streams. The construction window refers to the period of the year when the Washington Departments of Fisheries and Wildlife allow instream construction activities. Because it is defined by the presence of

Table 8.2. List of local growers and nurseries providing native species in and nearby King County.(Compiled from Shank 1991 and Baumgartner et al. 1991.)

Abundant Life Seed Foundation	Port Townsend	385-5660
Barfod's Hardy Ferns	Bothell	483-0205
Cascade Conifers	Olympia	754-6827
Colvos Creek Farm	Seattle	441-1509
Fancy Fronds	Seattle	284-5332
Fir Run Nursery	Puyallup	848-4731
Frosty Hollow Nursery	Langley	221-2332
Furney's Nursery	Des Moines	624-0634
Hood Canal Nurseries	Port Gamble	297-7555
IFA Nurseries - Nisqually	Olympia	456-5669
J. Hofert Forest Nursery	Olympia	786-6300
King County Conservation District	Renton	226-4867
Lawyer Nursery	Olympia	456-1839
Morning Glory Farms	Stanwood	629-4831
Newstart Nursery	Camano Island	629-3751
Pacific Natives & Ornamentals	Bothell	483-8108
Pacific Wetland Nursery	Kingston	297-7575
Peninsula Gardens Wholesale	Gig Harbor	851-8115
Silvaseed Company	Roy	843-2246
Storm Lake Growers	Snohomish	794-4842
Sweetbriar Nursery	Woodinville	821-2222
Tissues & Liners	Woodinville	885-5050
Warm Beach Nursery	Stanwood	652-5833
Watershed Garden Works	Olalla	857-2785
Webster Forest Nursery: DNR	Olympia	753-5305
Wetlands Northwest	Graham	846-2774
Weyerhaeuser	Rochester	273-5527
Weyerhaeuser	Tacoma	924-2547

The King County Department of Public Works does not endorse any of the above businesses or their products. This list is provided to the reader only as a general service in locating materials described in this document.

spawning salmonids or incubating eggs, the construction window varies from stream to stream. Planting times also vary with weather conditions, elevation, and other site conditions such as soil moisture.

Several options are available for construction that can not coincide with the construction window and yet must occur within the channel. On small sites it may be feasible to isolate the construction activity from flowing water with pile barriers, sand bags, coffer dams, or other means. At other sites, phased construction may be feasible. For example, the construction of the structural component, which is most disruptive to the stream, could be completed during the construction window, with the installation of vegetative system occurring during the following dormant season. Phased construction may increase overall project costs, especially if equipment has to be moved. Under certain conditions, however, it may be the most practical or only option available.

Another alternative is to use rooted plants instead of live cuttings so that vegetative elements of the project can be installed during the construction window. This option is generally more expensive as nursery stock must be purchased or grown.

In some cases, the construction window can be altered as much as a week by harvesting materials at higher elevations where they have either not broken dormancy (in the spring) or have entered dormancy (in the fall). Generally the differences in elevation should not exceed 1,000 feet, nor should plants be imported across major watershed boundaries. This helps protect the genetic integrity of local plant populations and reduces the chance of introducing disease organisms into healthy populations.

8.2.4 HANDLING, DELIVERY AND STORAGE OF PLANT MATERIALS

Live branch cuttings should be bound securely into bundles at the collection site for easy handling and for protection during transport. During bundling, the growing tips should be oriented in the same direction with side branches and limbs kept intact.

Branch bundles should be placed on the transport vehicles in an orderly fashion to prevent damage and facilitate handling. The material should be covered with a tarpaulin during transportation to prevent additional stress from drying. Damp burlap draped over plant materials or placing the cuttings in moist sand will provide additional humidity and reduce drying of cut ends. While latex paint is often recommended to seal, and, sometimes can be helpful in identifying the upright end of live stakes, its use can be very messy and does not seem to appreciably increase plant survival.

Plant material should be harvested and delivered to the project site as quickly as possible, especially on warm (more than 50° F), windy, or low-humidity days. For maximum survival, cut plant material should arrive at the job site within eight hours of cutting. Vegetation for live stakes or other similar use should be used the same day that it was cut and trimmed. If the air temperature is 50°F or higher, all live materials should be installed on the day they are cut. Although not optimum, material not installed on the day it was cut can be installed later if the air temperature is less than 50°F. Because live plant material often deteriorates and is less effective when held for long periods, all fresh cut plant materials should be used within two days after cutting unless refrigerated.

Protect all plant material from drying by storing it in shady, moist areas, placing it in fresh water or in cool storage if it must be stored for several days. Outside storage locations should be continually shaded and protected from the wind. Water used for keeping cuttings or rooted material moist should be free of substances toxic to the plants such as petroleum products or excessive amounts of nutrients.

Plant roots must not be allowed to dry. Exposure of root systems to drying agents such as sun or wind is the cause of many planting failures. Desiccation of roots results in the plants effectively being unrooted cuttings when planted. Low temperatures and high humidity, preferably refrigerated storage, are ideal storage conditions. If cool storage is not available or if planting is delayed, plants should be “heeled in” until they can be planted. This practice consists of loosely planting the vegetation (whether containerized, balled and burlapped, or bare root stock) in a temporary location in the shade to prevent desiccation of or heat damage to the roots.

Even container plants should be kept in the shade to reduce stress. The soil in a black plastic container can exceed 120°F and remain above 100°F for several hours. Temperatures of 104°F for only four hours is lethal to root tips of most plants. If plants begin to wilt and the root ball appears very dry, set the plant in a pail filled with water and allow it to soak the water up slowly. While water should not completely cover the root ball, there should be sufficient water to thoroughly wet the entire ball. Tree seedlings (trees less than one year old) should not be stored with their roots submerged in water (Pitkin and Burlison 1982). Bareroot trees and shrubs, however, may be soaked for one to two hours prior to planting (Maleike and Hummel 1988). Do not saturate or submerge the plant for more than two hours.

When using rooted stock, it is advisable to store this material somewhere other than the project site where it may be prone to vandalism or theft at night. Also, in areas of heavy traffic, barriers should be erected to keep plants from being damaged (trampled or uprooted).

8.2.5 GENERAL INSTALLATION PROCEDURES FOR PLANT MATERIALS

In all situations where vegetative methods are used, it is critical to provide good contact between soil and plant material (cuttings, seed, or rooted stock) for root development. All fill around live plant cuttings should be compacted by foot or by machine to densities similar to that of the surrounding natural soil, taking care not to damage roots in the process. The soil around plants should be free of large air pockets.

Undesirable soil compaction during the planting phase may be prevented or reduced by limiting operation of machinery on wet soil. Where compaction is unavoidable or soil is already compacted, tillage can alleviate the condition following earthmoving and prior to planting. The tillage can be accomplished using a bulldozer equipped with either subsoilers, brush blades or rock ripper teeth attachments. It is necessary to loosen the soil to a depth of at least 12 and preferably 24 inches for satisfactory results.

Soil backfill should be free of any material or substance which could be harmful to plant growth. Gravel is not a suitable material for use as fill around live plant materials, nor should it be placed in the bottom of planting holes to improve drainage. Saturated soils that otherwise meet fill requirements should not be considered suitable fill material until dried to an acceptable moisture content. Soil having an appropriate moisture content, when formed into a ball, should crumble when pressed between the thumb and fingers. If the ball sticks together, the soil may be too wet to be properly worked. Heavy clays should not be mixed with sand to improve texture as this usually results in irregular pockets of sand and clay rather than a uniform mixture. If the clay content of a soil is very high, it may need to be replaced with more suitable fill. While the fill does not need to be organic topsoil, it must be capable of supporting plant growth.

Some perennial grasses such as reed canary grass may compete with installed vegetation for water and nutrients. If present, this vegetation should be removed or controlled prior to planting. Preliminary mechanical control (tilling or cutting) should be used to reduce initial competition and allow easier placement and planting of selected species. While chemical control may be required in some situations, many herbicides are highly toxic to aquatic organisms. Extreme care is required if these chemicals are used. In any case, it is desirable to limit the use of any pesticide near water bodies to reduce the chance of water contamination.

Mechanical methods to control undesired vegetation include disking, harrowing, and scalping. On uneven ground or steep slopes with dense ground cover where shrubs and trees are desired, or in areas where large vegetation is being saved, scalping may be the most suitable. It requires removal of the above-ground portion of competing vegetation (root removal enhances effectiveness) from an area about 30 inches in diameter. The plant, cutting, or live stake is then placed in the center of the scalped area.

Follow-up control in succeeding seasons may be required (Pitkin and Burlison 1982). If fertilizers are to be used where competition from weeds may be a problem, use fertilizer tablets or spikes that are placed below the soil surface, (e.g., worked into the backfill or root ball) or slow-release fertilizers to avoid encouraging excessive growth of weeds.

8.3 INSTALLATION PROCEDURES FOR DIFFERENT METHODS

As outlined in Chapter 7, there are three general types of bank stabilization methods: rock, vegetative, and integrated methods. General procedures for installing each of these methods will be discussed in the following sections. Schiechtl (1980), Gray and Leiser (1982) and Coppin and Richards (1990) describe installation of these methods in detail.

8.3.1 ROCK PROTECTION METHODS

Successful installation of rock methods relies mostly on appropriate equipment selection and operation, and the experience of the personnel installing the system. The specifics of selecting equipment, other than having equipment large enough to handle the specified rock, is not discussed herein.

As with other methods, all construction must adhere to the permitting requirements described elsewhere in this document. Instream construction should take place during low-flow conditions, and during a time of minimal fish usage as prescribed by Departments of Fisheries and Wildlife through their Hydraulic Project Approval process.

Construction of the rock toe key can be difficult, particularly in large rivers where flow depths may be significant. Because the toe is keyed in, not just end-dumped, excavation of the existing lower streambank may be necessary. The bottom of this toe should be keyed into the channel below the anticipated scour line, as described in the general design considerations listed in Chapter 7. Failure to observe this precaution is a common cause of failure.

When planning for toe excavations, permit provisions and construction may require separating the work area from the main flow. The construction of the toe key usually involves diverting the flow, removing fish (if present) from the area to be dewatered to prevent stranding, dewatering of the construction area, and implementing sediment control measures. Depending on the size of stream and flow conditions during construction, a simple diversion such as a small instream dike constructed of sandbags may be sufficient to separate the work area from the main flow. In larger rivers, where flow depths are significant, installation of temporary cofferdams using sheet piling driven into the river bottom may be necessary.

Because the methods mentioned above will not completely eliminate seepage into the construction area, dewatering may be necessary. Water from dewatering operations should be pumped to vegetated upland areas or settling ponds to remove sediment before discharging it back to the receiving water. Erosion and sediment control systems should be designed and installed as part of the streamflow diversion and dewatering systems.

For construction, it is usually most practical to use equipment stationed on the top of the bank to reach down, excavate, and place the rock. This depends on the bank height and having a right-of-way or an access road. If the bank is higher than the equipment reach length, construction of a bench at the ordinary high water line facilitates equipment access. In extreme cases, where right-of-way and bank height constraints combine to make construction from above not feasible, equipment such as a “spider hoe” can “walk” up the stream and perform the work from within the channel. If this method is considered, it is very important to be aware of fish usage of the project area during the construction period. In larger rivers, where flow depths and velocities are suitable, performing construction from a barge may provide another alternative.

Prior to placing riprap, the banks should be graded to a 2H:1V side slope or flatter. Depending on its size, riprap may be either hand-placed, end-dumped, or placed by derrick crane. Most riprap is placed on a filter blanket of smaller sized, graded material (gravels and spalls) that is typically eight inches thick. The area to be covered with a filter blanket should be reasonably smooth. An even thickness of filter material should be placed on the prepared surface. Care must be exercised when placing the riprap to ensure that the blanket is not ruptured or displaced. The riprap should extend up the bank far enough to give adequate protection against scour by debris, flowing water, or wave action.

8.3.2 VEGETATIVE METHODS

Herbaceous Ground Cover

Numerous methods exist for establishing turf. These include laying sod (e.g., “instant lawn”), hay and straw seeding, broadcast seeding, hydro- and dry seeding, and foam seeding. While sod, hay and straw, and broadcast methods are often installed with hand labor; specialized equipment is required for hydro-, dry, and foam seeding. Seeds should be sown at no more than 20 pounds per acre to prevent depleting moisture and nutrients in poor soil (Sears and Mason 1973). This, however, may vary with local conditions. Drills are preferable to broadcast seeding. The California Department of Water Resources (1967) reports that almost all grass test plots sown in spring did better than those sown in the fall. Whatever the method, seed-to-soil contact is essential for germination and seedling establishment. If seed germination is poor, reseed thin areas as soon as possible to prevent erosion.

Streambanks to be protected with turf should be sloped to a stable grade, normally 2H:1V on outside meander bends (concave bank) and 3H:1V or less in straight reaches. If right-of-way space is available, compound bank designs that include walkways or recreational facilities within the berm area are ideally suited for turf.

Rooted Stock

Rooted material may be planted in slits or planting holes, depending on the size of the root mass. Slit planting involves inserting a spade into the soil and rocking it forward to create a space. The plant is placed in this space and the soil is then tamped back around the roots.

Planting holes for rooted stock should be as deep as and twice as wide as the root mass to promote the lateral spread of roots (Figure 8.1a, b, and c). If the soil is severely compacted, break up more soil under the root ball to encourage root penetration; do not, however, add soil amendments.

Nursery stock should be planted from 0.5 inch deeper to 2 inches higher than it grew in the nursery (Pitkin and Burlison 1982, Maleike and Hummel 1988). The root crown should be at or slightly above the level of the surrounding soil. Planting with the root crown too low, especially in soil that is apt to settle with time, can result in crown rot from excess moisture. Partially loosen rootballs and mix the planting medium with the native soil to reduce soil interfaces that can impede water movement and root growth. Circling roots should be straightened or cut before planting.

The planting hole should be backfilled with native soil, NOT topsoil. The soil loosened from the root ball should be mixed with the native backfill material. Adding large amounts of organic material, topsoil, or soil of a texture substantially different from the native soil does not improve plant growth and may be detrimental. Large differences between planting hole soil and surrounding soil result in difficulties in moisture regulation. For example, if the native soil is heavy or somewhat compacted (as many northwest soils are) and the planting hole is backfilled with loamy soil, the planting hole functions much like a large clay pot and frequently drowns the plant during wet weather. During dry weather, the plant is subjected to excessive drought because of lower water holding capacity of soil in the planting hole.

The backfilled material should be gently tamped around the root ball; this can be achieved by watering the soil while backfilling the planting hole. A “tree well” or watering basin may be

Figure 8.1a Installation of rooted stock—single-stem tree.

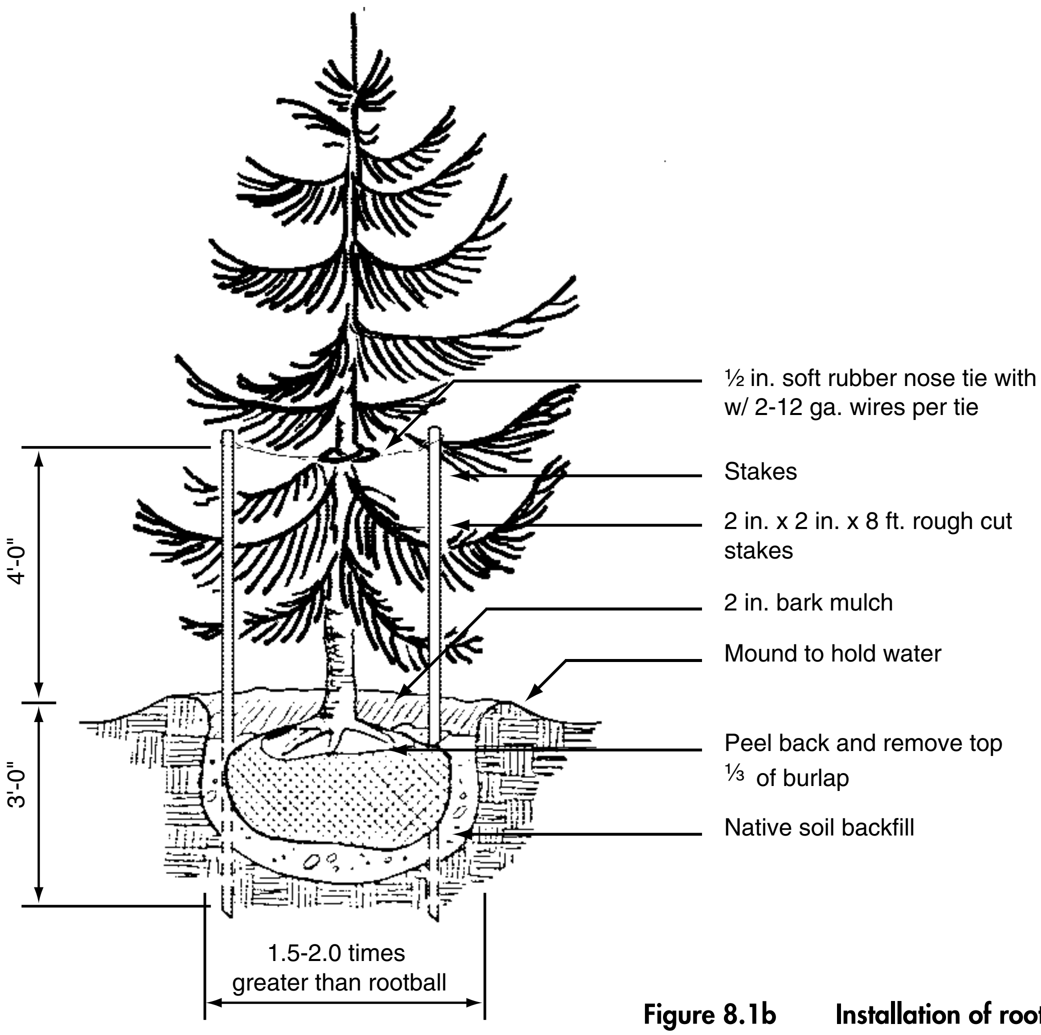


Figure 8.1b Installation of rooted stock—shrub.

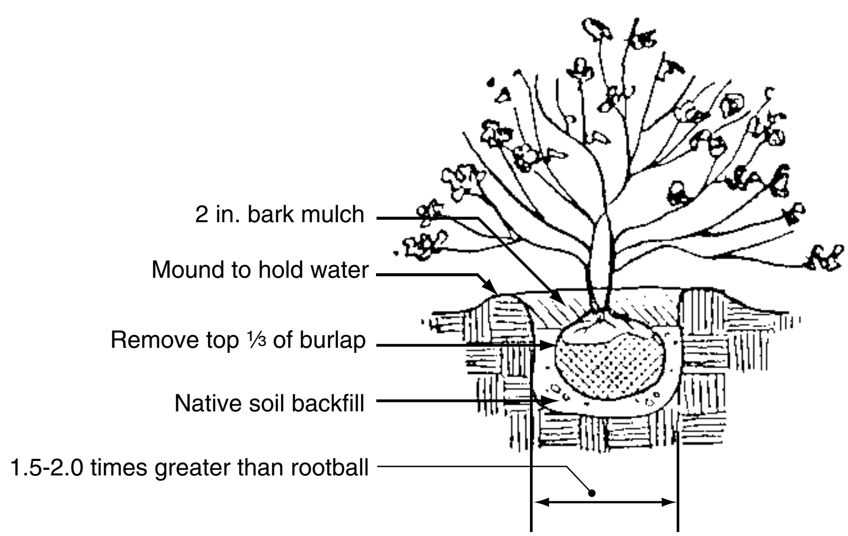
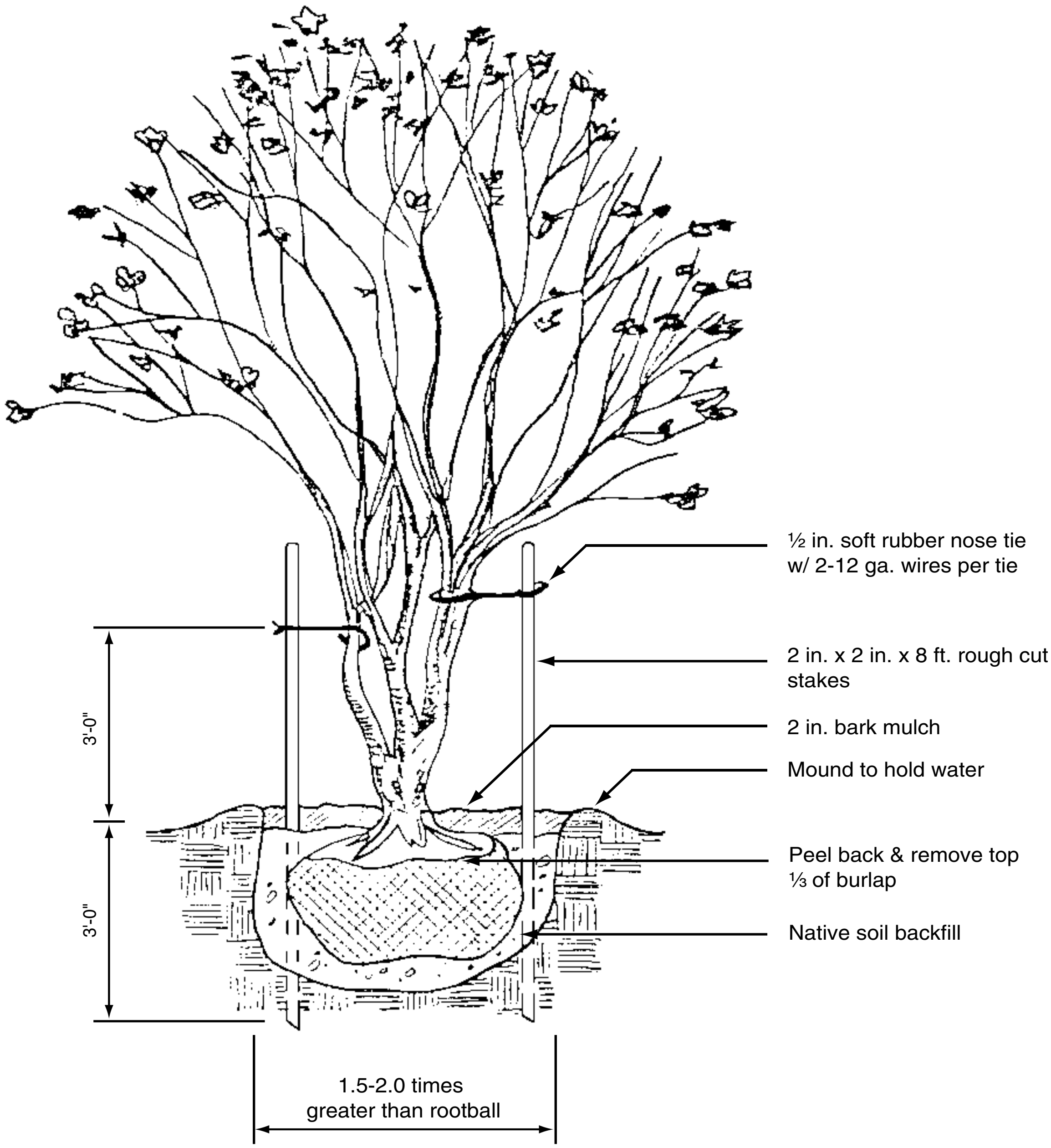


Figure 8.1c Installation of rooted stock—multi-stem tree.



formed around the edge of the planting hole. This can be especially important on slopes that might not intercept sufficient rainfall. The plant should be well watered once at planting, then not again for at least one week unless signs of drought stress are visible. This encourages roots to grow outward from the planting hole. Roots that extend from the root ball (e.g., circling roots that can be straightened) and the roots of bare-root stock should be surrounded by native soil. This speeds the acclimation of the plant to the site and improves long-term survival.

While soil amendments are typically not needed, slow-release fertilizers occasionally are beneficial. Regular commercial fertilizers and fresh manure should not be used as they can cause severe damage to recent transplants.

Ensure that the roots are arranged in a natural position, i.e., pointing generally down and away from the root crown. Circling roots can lead to girdling and eventual death of the plant. Any circling or badly kinked roots should be straightened or removed. When the plant is at the desired height, fill around the roots with loose soil. Simply stepping gently (not putting full weight) on the soil a few inches from the trunk all the way around is generally adequate to firm the soil. With balled and burlapped stock, it is essential to remove all wire, strings and twine to prevent girdling the plant. If a synthetic burlap was used, it should also be removed. Mulch may be needed around the plants to maintain moisture and moderate temperatures. Information on mulches is provided in Chapter 6.

It is not necessary to prune the top of plants when they are transplanted. Studies have shown that unpruned trees actually recover more quickly from transplant shock than pruned trees. It is beneficial, however, to remove dead or diseased branches and those that cross and rub against one another. If plants must be staked to prevent them from toppling, remove the ties as soon as possible (usually after one year). Ties can also girdle trees, and unstaked trees develop stronger, more flexible trunks.

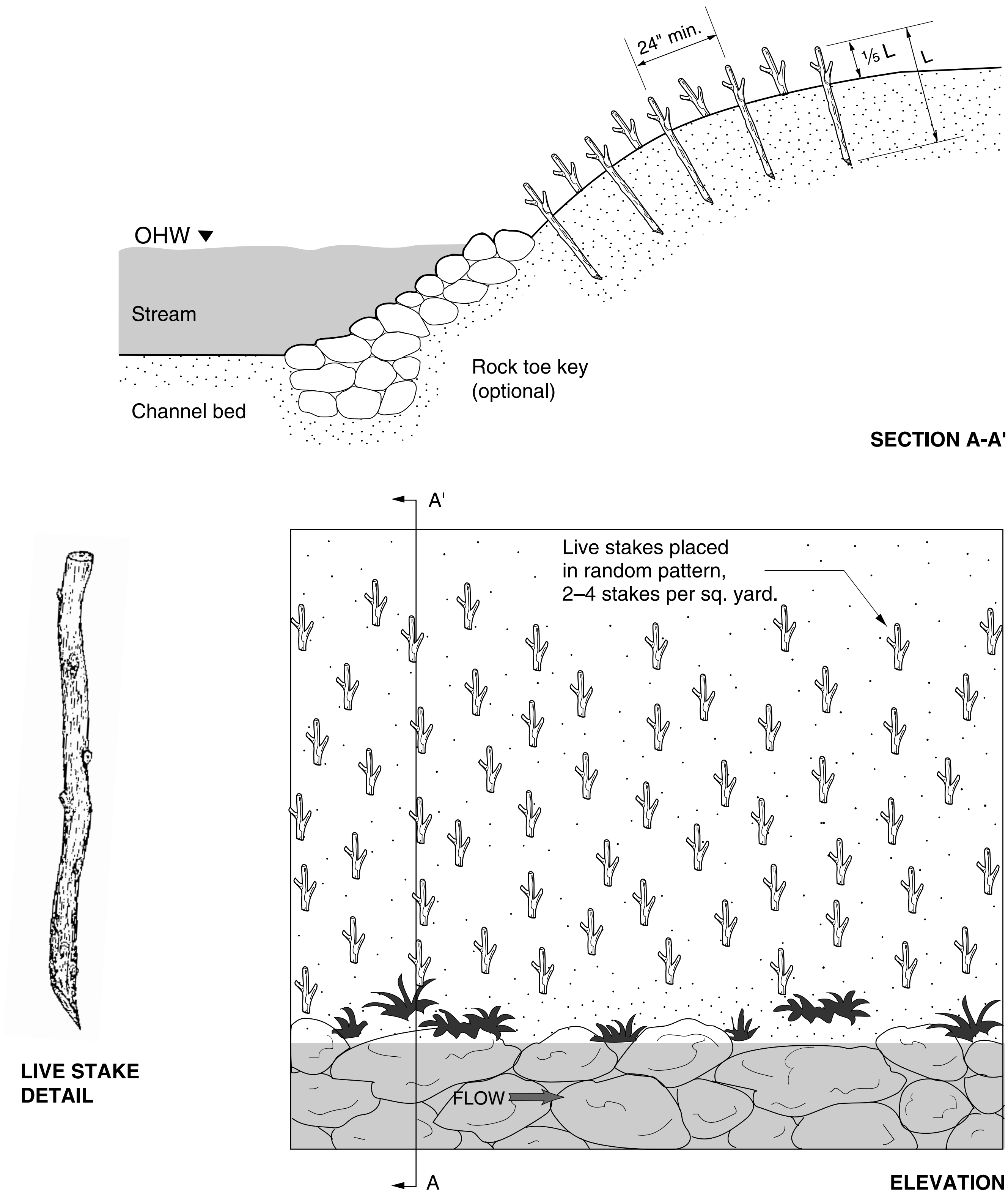
Quality control is important for project success. Reject dead, obviously unhealthy plants and those with excessive broken branches or damaged roots. Plants with viral or fungal diseases or insect infestations are a source of disease for entire plantings and should be removed from the site. Appendix D provides an example of plant quality specifications.

Live Stakes and Slips

Cuttings for live stakes must be from a species with large sturdy stems, one to two inches in diameter. Slips (0.2 to 0.5 inch in diameter) can be cut from any branch large enough to handle easily. In either case, the cuttings must be alive with side branches removed and with the bark intact. The basal ends should be cut cleanly at an angle for easy insertion into the soil; the top should be cut square or blunt (Figure 8.2). Slips are most easily prepared by making each cut at an angle. Stems should be cut into two to three foot lengths for live stakes, one foot for slips. Larger diameter branches may be cut longer. These cuttings should be kept moist after they are cut and ideally installed the same day that they are prepared. If it is necessary to store cuttings, they should be protected from dehydration (e.g., placed in moist peat in plastic bags) and either frozen or kept slightly above freezing (Platts et al. 1987). Prior to planting, frozen cuttings should be stored for two or three weeks at 41°F to break dormancy.

To plant, tamp live stakes into the bank with a dead blow hammer (i.e., a hammer with the head filled with shot or sand). Live stakes should be installed with the upright end exposed (i.e., the end that was up prior to being cut) and the butt end pushed into the soil. In firm soil, an iron bar may be needed to make the pilot hole. The diameter of the iron bar should be slightly smaller than the cutting to ensure a snug fit. Slips are pushed into the soil by hand. Live stakes should be placed at right angles to the slope with four-fifths of the length inserted into the ground to prevent drying. The soil should be firmly packed by foot around the cutting after it has been tamped into the ground. Replacing any cuttings that split or break during tamping is optional, as some may survive if they are not badly damaged. A plant loss of 30 to 50

Figure 8.2 Installation of live stakes shown with an optional rock toe key.



percent is common with this method (Schiechtl 1980; Christensen and Jacobovitch 1992)

The density of the installation ranges from two to four cuttings per square yard. Live stakes should be placed in a random to triangular configuration with a spacing of two feet or greater. For slips, higher density (about 12 cuttings per square yard) at one foot spacing is recommended.

Fascines

Fascines require long, straight branches; young willow or dogwood 0.4 to two inches in diameter is ideal for this method. Stems may be any length over three feet--the longer the better. The cuttings are prepared in bundles of at least five stems with a minimum diameter of 0.5 inch tied together with the direction of the growing tips alternated randomly (Figure 8.3). The number of stems varies with the size and kind of plant material. The bundles should be 8 to 10 inches in diameter. For ease of handling, bundle length typically varies between 10 to 30 feet. Bundle lengths can be extended by interlacing the ends of bundles. Fascine bundles can be tied with string such as baling twine or hemp. They should be snug but not so compressed that soil will not filter in among the twigs. Both live and dead stakes at least two feet long are used to secure the fascines.

Beginning at OHW, dig a shallow trench one-half to two-thirds the diameter of the bundle (six inches deep and eight inches wide). To minimize drying of the soil, trenching should not precede laying of the bundles by more than one hour (Gray and Leiser 1982). When placing the bundles, care must be taken to overlap (i.e., interlace) the tapered ends of the bundles to ensure that the overall thickness is uniform. After placing the fascine into the trench, drive the dead stakes directly through the bundle. Extra stakes should be used where the bundles overlap. Leave the tops of the stakes flush with the installed bundle. Place and compact soil along the sides of and into the bundles.

Stakes must be installed directly through the fascine bundle to initially secure it from moving during flood events. Tamp the live stakes between the previously placed dead stakes, and on downslope side of the bundles. Repeat the entire process at three to five foot intervals to the top of the bank.

Soil must be well worked into the bundles for good rooting to occur and to prevent ditches from collecting water. Collected water can drown cuttings and cause erosion by flowing along and across the slope (Gray and Leiser 1982).

Gray and Leiser (1982) provide further information on the installation of fascines.

Brush Mattresses

For this technique to be successful, it is essential that the branches are in contact with the soil. The butt (i.e., the basal) ends of the branches should be covered so they can root and not dry out or be washed away. There are two methods for protecting the branches: 1) placing the butt ends into a shallow trench and covering the ends with soil; and 2) placing the branches in a shingle-like manner and covering the mattress with a layer of soil. If the length of the branches is not sufficient to cover the entire length of the slope, the branches in the lower layer must overlap the upper layer by at least 12 inches (Schiechtl 1980). A slope for a brush mattress installation should be laid back to a uniform grade of 1.5H:1V or flatter (Figure 8.4).

Lay branches with butt ends in a shallow trench with tips pointing upslope. To ensure rooting, the branch layer, 4 to 18 inches thick, should lie smoothly against the bank. If additional protection is desired, place a fascine in a trench on top of the basal ends of the branch mattress. To anchor the mattress, place live or dead stakes that slightly protrude above the brush layer over the face of the bank in a square or diamond pattern two to three feet apart. Dead and live stakes are also used to secure the fascine. Attach the wire (e.g., 20 gauge electrical fencing) to the stakes and wire down the mattress branches as close to the slope face as possible. Tighten the wire by tamping the stakes further into the bank. Cover the brush mattress with a sufficient amount of soil to ensure good soil contact, leaving some buds and twigs exposed. Although wire has been specified for securing the brush mattresses to the bank face (Schiechtl 1980),

Figure 8.3 Installation of fascine bundles. (Adapted from Gray and Leiser 1982.)

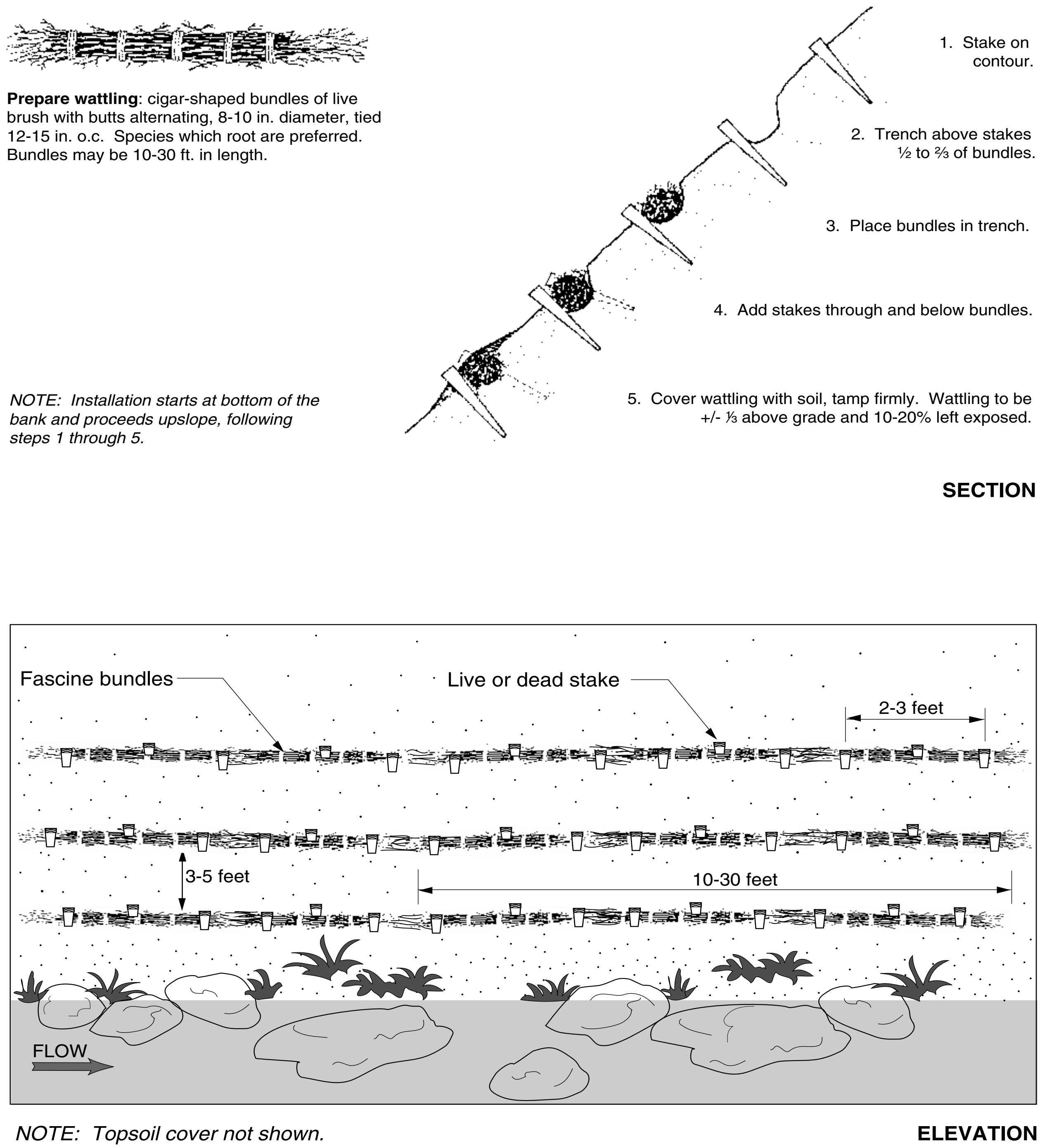


Figure 8.4 Installation of a brush mattress shown with an optional fascine and rock toe. (Adapted from Gray and Leiser 1982.)

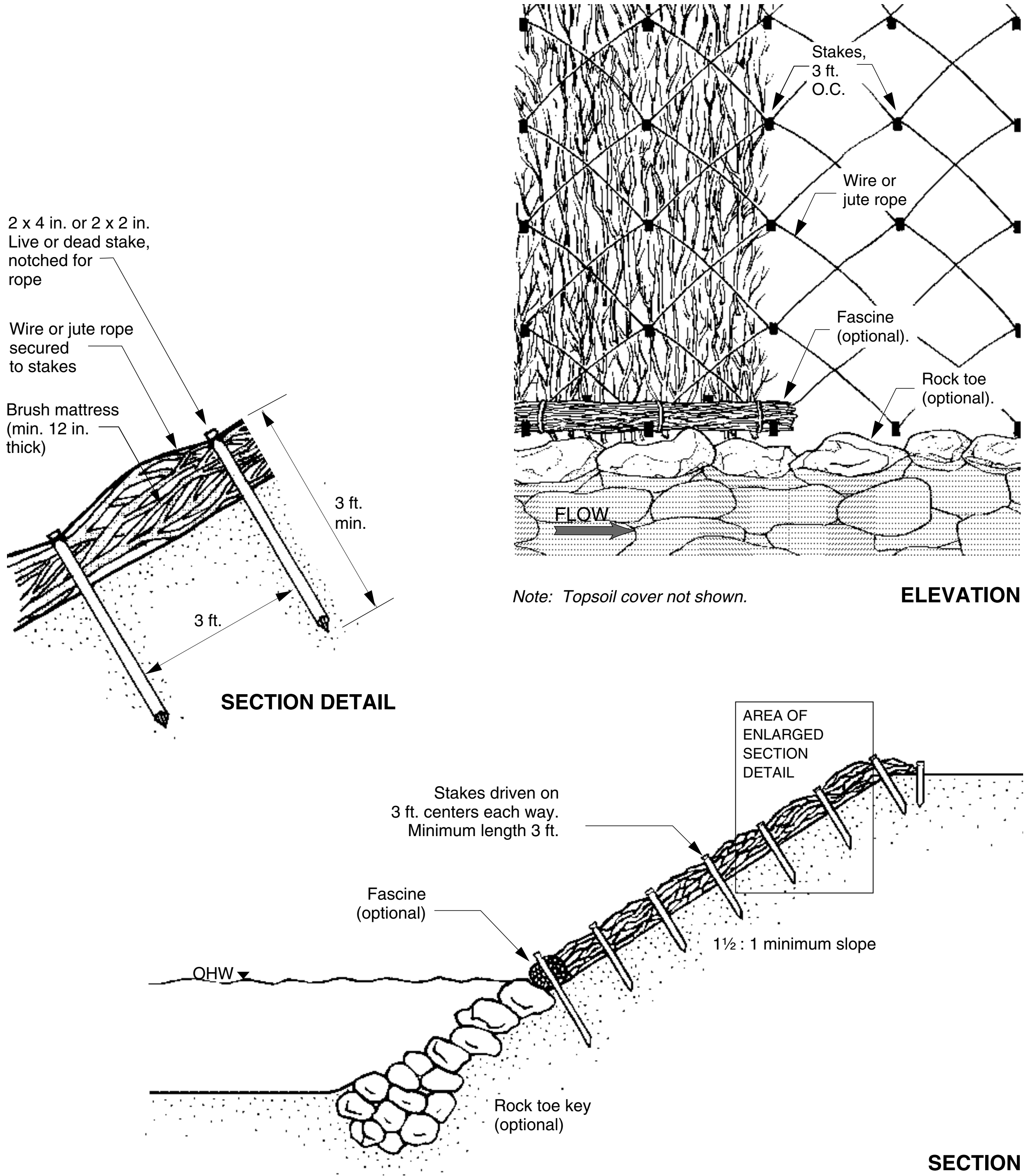
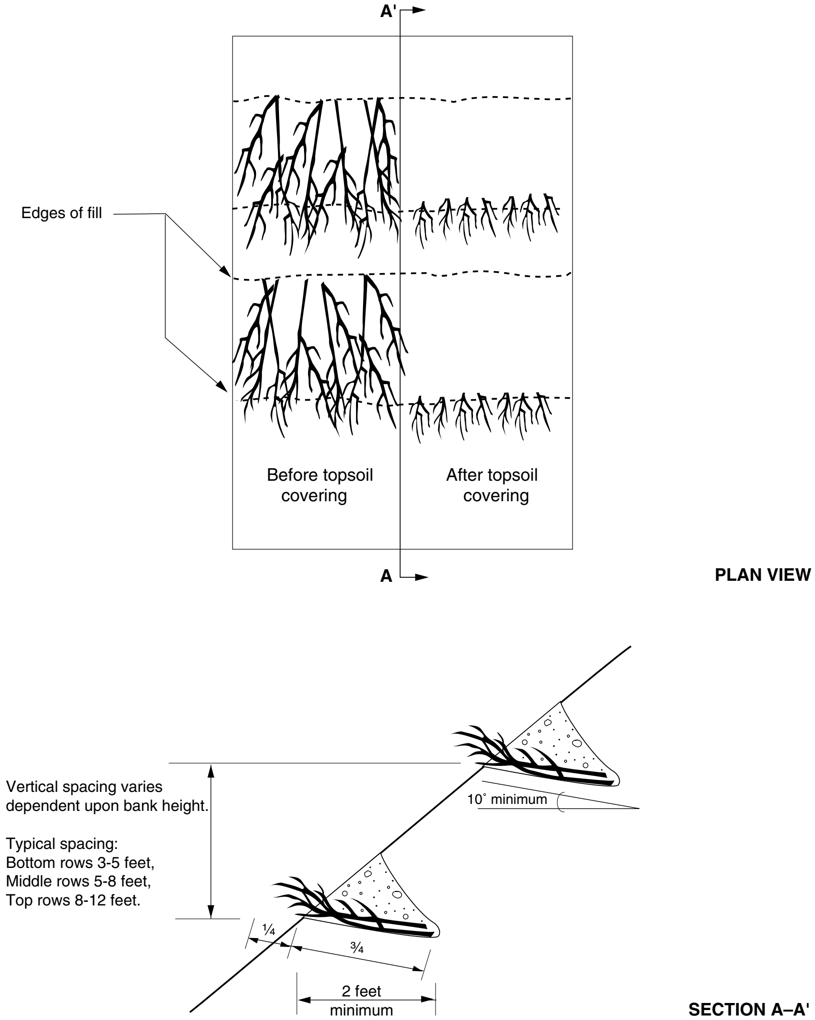


Figure 8.5 Installation of brush layers. (Adapted from Gray and Leiser 1982.)



jute or hemp rope, or coir fabric has also been used successfully (A. Levesque, King Co. Pub. Wrks, pers. comm.).

Brush Layers

Brush layers consist of embedding live branches or rooted stock on successive horizontal rows in the face of a slope (Figure 8.5). Beginning at OHW, terraces (two foot minimum depth) are dug in the bank face either manually or with machinery. The platform of the terrace should slope up at least 10 degrees to the outside so that branches can root along their entire length (Schiechtl 1980). If constructed concurrently with a fill slope, the branches are layered between successive layers of fill. Fill soil used between the layers of branches must be material that can support plant growth.

The live branches used for constructing brush layers should be 20 to 25 percent longer (three foot minimum length) than the depth of the terrace. The branch layer should be four to six inches thick. The branches are placed in a random, crosswise pattern (not parallel to each other) so that the pieces are covered with soil as far as possible (Schiechtl 1980). The butt ends should angle down slightly into the slope, and the tips should protrude slightly beyond the face of the slope (Gray and Leiser 1982). It is important not only to mix branches of different species, but also branches of different ages and thicknesses (Schiechtl 1980). This provides deeper penetration of the roots, and more variety in the above-surface growth.

In fill slopes, the branches should be covered with a minimum of 12 inches of soil. Vertical spacing between brush layers will be dictated by the erosion potential of the bank (i.e., the soil type, rainfall, water velocities, and length and steepness of the cut or fill slope). It may be as little as three feet to more than nine feet (Gray and Leiser 1982). On high banks, the layers should be spaced closer at the bottom of the bank and be spaced further apart as one moves upslope (Gray and Leiser 1982).

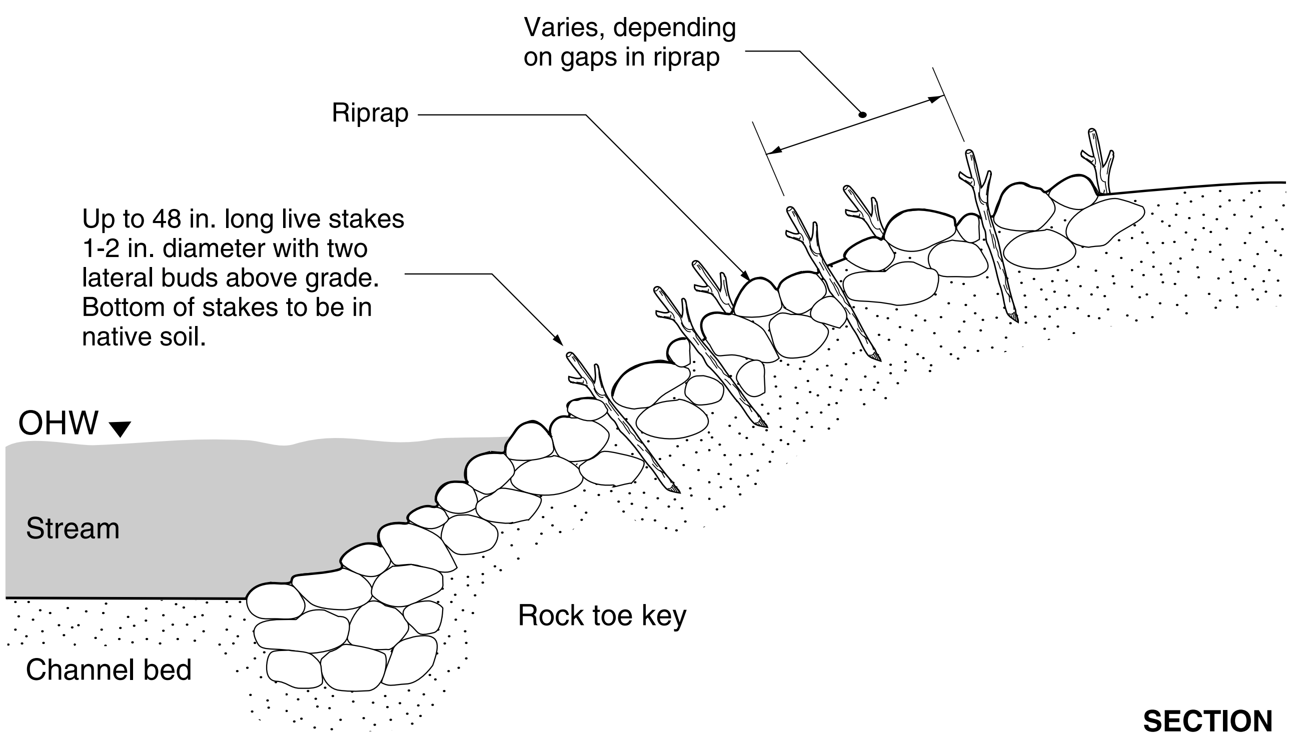
Schiechtl (1980) and Gray and Leiser (1982) provide further discussion of the installation of brush layers.

8.3.3 INTEGRATED METHODS

Joint Planting

The thickness of the existing rock layer is a major consideration in applying this technique. To achieve successful rooting, live stakes must be driven through the rock voids and into the underlying soil layer (Figure 8.6). The stakes must be alive, with side branches removed and with bark intact. The live cuttings should be sufficiently long (up to four feet) for the base end of the stake to penetrate the soil (two feet if possible) in the

Figure 8.6 Installation of joint planting.



backfill or interstices. The basal ends should be cleanly cut at an angle for easy insertion into the soil; the top should be cut flat.

Cuttings must be fresh and must be kept moist (in damp peat moss, sand, soil, or plastic bags) after they have been cut into appropriate lengths. They should be installed the same day they are harvested.

Tamp the cutting into the bank using a dead blow hammer (i.e., a hammer with the head filled with shot or sand). In firm soil an iron bar may be needed to make the pilot hole. The iron bar should be slightly smaller than the diameter of the cutting to ensure a snug fit. If the rod is of slightly larger diameter, backfill the hole with sand or other fine soil around the stake. Where possible, the stakes should be tamped in at right angles to the slope. Tamp about 0.8 of the length of the stake into the ground beneath the riprap. To prevent desiccation, it is important not to have a long length of stake exposed. If necessary, the exposed end can be trimmed to reduce moisture loss from the stake.

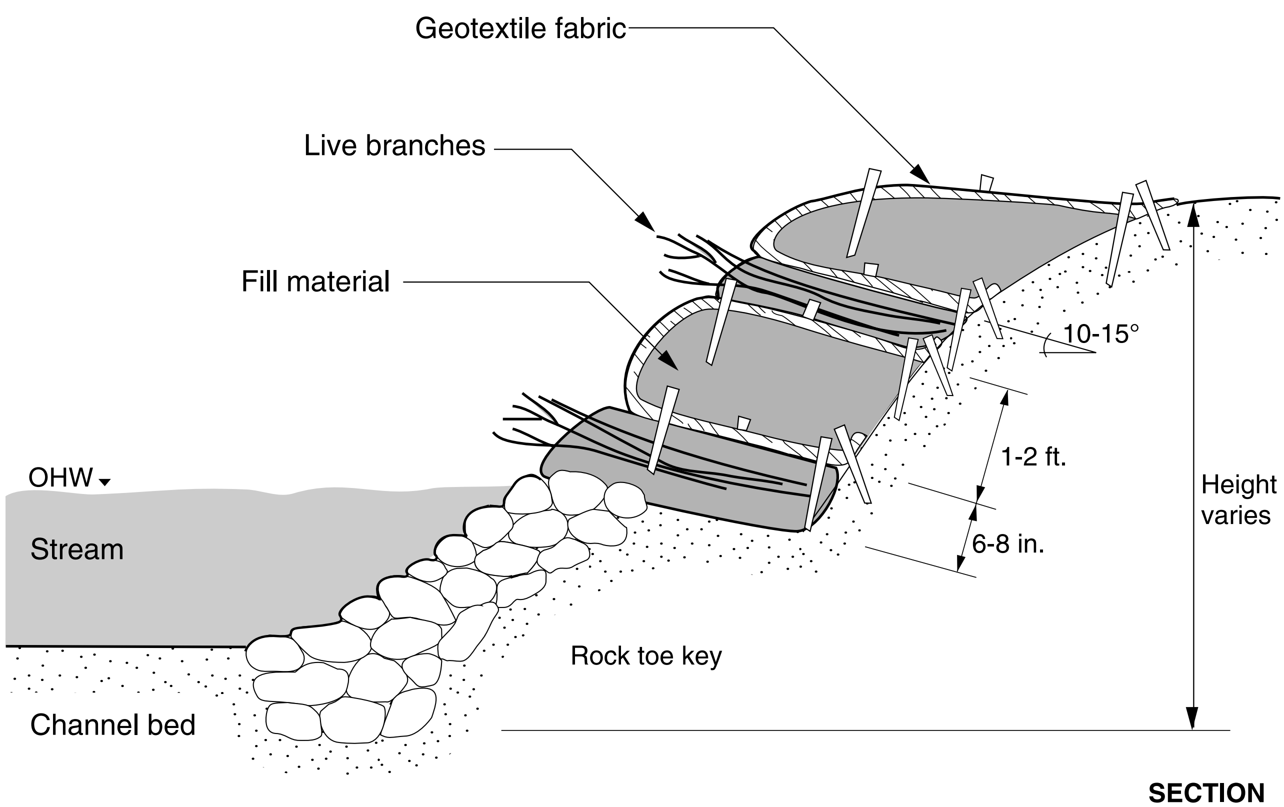
If construction of the rock system occurs during the dry season, it may be possible to drive live stakes between the rocks at a later date. If a portion of the backfill consists of small rock or gravel, the cuttings should be of sufficient length to reach native soil.

Vegetated Geogrid

Vegetated geogrids are very similar to brush layers except that the fill soil in the alternating layers is wrapped in a natural geotextile material (Figure 8.7). Vegetated geogrids can be installed over rock toe protection.

Geogrids in smaller projects are generally shaped by hand. To facilitate building larger, longer geogrids, excavation equipment can be used to

Figure 8.7 Installation of a vegetated geogrid shown with an optional rock toe key.



shape the geogrid; construction jigs and batter boards may also be used (Figure 8.8). The jigs, which are constructed of angle iron, hold the batter boards that shape the face of the lift to match the existing slope contours. Shorter batter boards (three to four feet long) and sufficient jigs will facilitate this process. After completing the lift, the jigs are removed with a backhoe.

Begin construction by excavating and shaping the bank to create a bench with a 10 to 15 degree backslope. Place at least six inches of fill material over the bench followed by a layer of live branches. The live branches should be 20 to 25 percent longer than the depth of the bench (three foot minimum length). The branch layer should be four to six inches thick. The branches are placed in random, crosswise pattern (not parallel to each other) so that the individual pieces are covered with soil as far as possible (Schiechtl 1980). The butt ends should angle down slightly into the slope, and the tips should protrude slightly beyond the face of the slope (Gray and Leiser 1982). It is important not only to mix branches of different species, but also branches of different age and thicknesses (Schiechtl 1980). This provides deeper penetration of the roots, and more variety in the above surface growth. The brush is then covered with a layer of topsoil and lightly compacted to remove air pockets and work the soil in and around the brush. Maintain a 10 to 15 degree backslope. If constructed during the dry season, thoroughly wet each layer of branches and topsoil.

Next, place the jigs and batter boards for the face of the first wrapped lift. Lay pre-cut strips of geotextile on the bench. The geotextile strips should be slightly longer than two bench widths (i.e., two bench widths plus the height of the lift). Beginning at the upstream end of the project and working downstream, lay the geotextile strips so that the downstream strip overlaps the upstream strip by 1.0 to 1.5 feet. The remainder of the material (slightly more than half of the fabric) should be draped over the batter boards.

Secure the geotextile strip by staking the rear portion of the strip to the soil beneath it. Set at least two rows of stakes. Commercial construction stakes 12 to 24 inches in length work very well for staking.

Backfill the lift with specified material (excavated native soil, or specified soil mixture). Compact the soil to create 1.0 to 2.0 foot lifts; maintain a 10 to 15 degree backslope with each lift. Starting at the downstream end of the project site, flip the remaining geotextile material of the most downstream strip over the backfill. After stretching the geotextile so that it is snug, secure it by staking. If possible, stake the material into native ground. To complete the lift, work in an upstream direction following this sequence of steps for each strip.

Remove the batter boards and repeat the process beginning with the next layer of branches. The process continues until the structure is at final, specified height. The geogrid structure does not always need to be built to the original bank height; the upper bank may be completed with other systems.

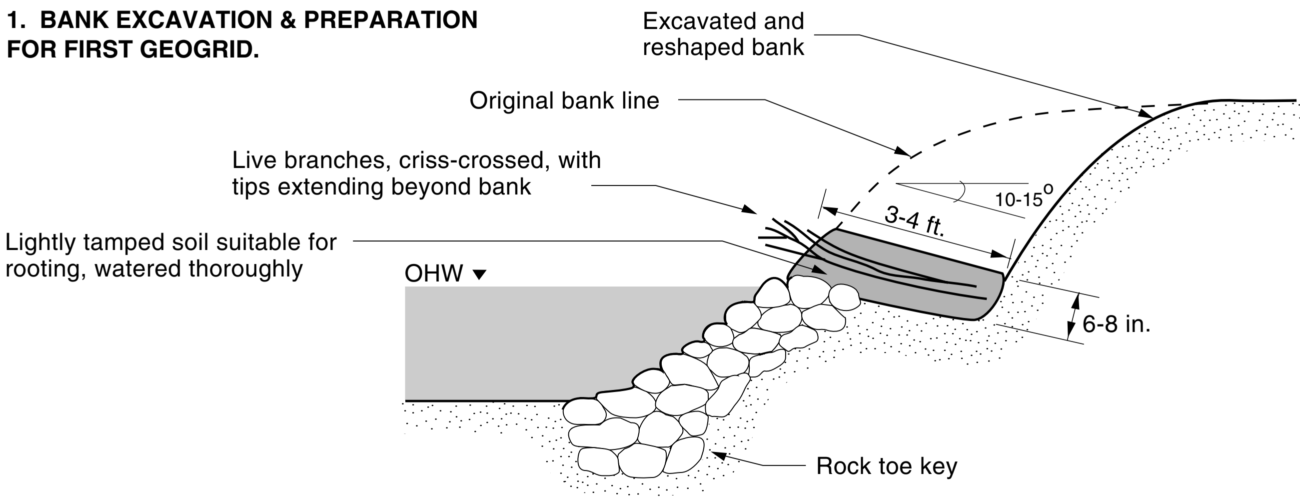
There are several options for protecting and tying in the ends of the lifts. One method is to add additional strips at the ends of each lift. This strip is laid perpendicular to the lift strips. When positioning these extra strips, the upstream end strip is laid first, and then covered by subsequent lift strips (i.e., the first lift strip is contained by the end strip). Downstream, the end strip is the last strip to be positioned (i.e., contained within the last lift strip). Beginning with the downstream end strip, fold and secure the strips in the sequence as described above for constructing the lifts. Another method is use leave extra material at the end points of the lifts. This material is folded and staked using "hospital corners" to lap and tuck the material snugly into place. Protecting the end points of the lifts can also be achieved by tying into existing stable features or by placing rock or large woody debris.

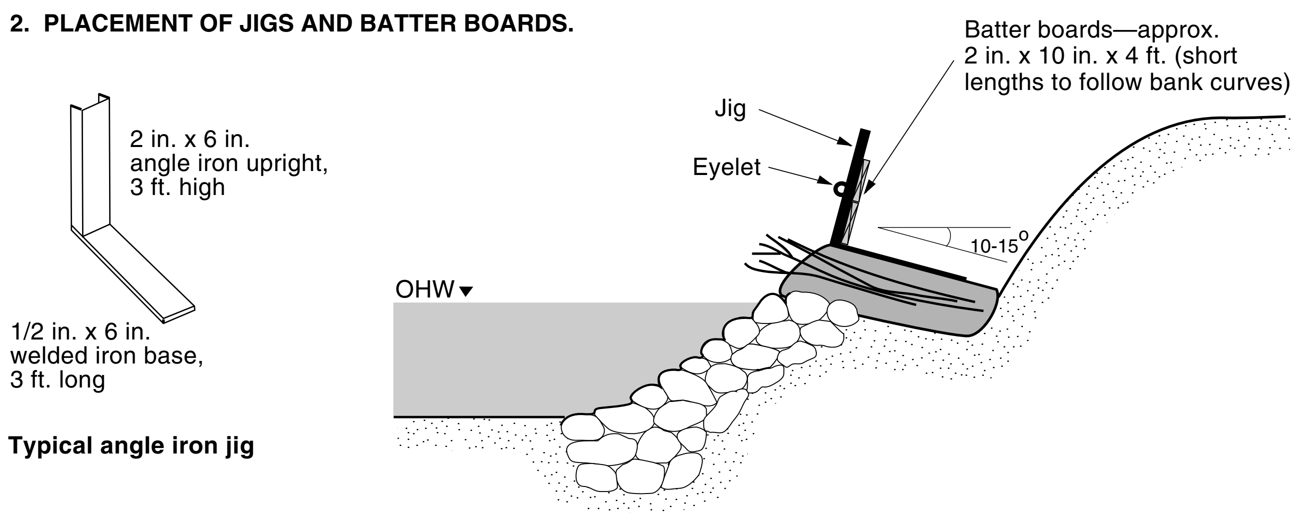
Live Cribwall

The following discussion is limited to simple cribwalls less than six feet in height. A engineer knowledgeable with cribwall design should be consulted if constructing a larger or more complex structure.

Timbers, either round or square, 4 to 10 inches in diameter and in varying lengths, are required for

Figure 8.8 Vegetated geogrid installation using construction jigs and batter boards.





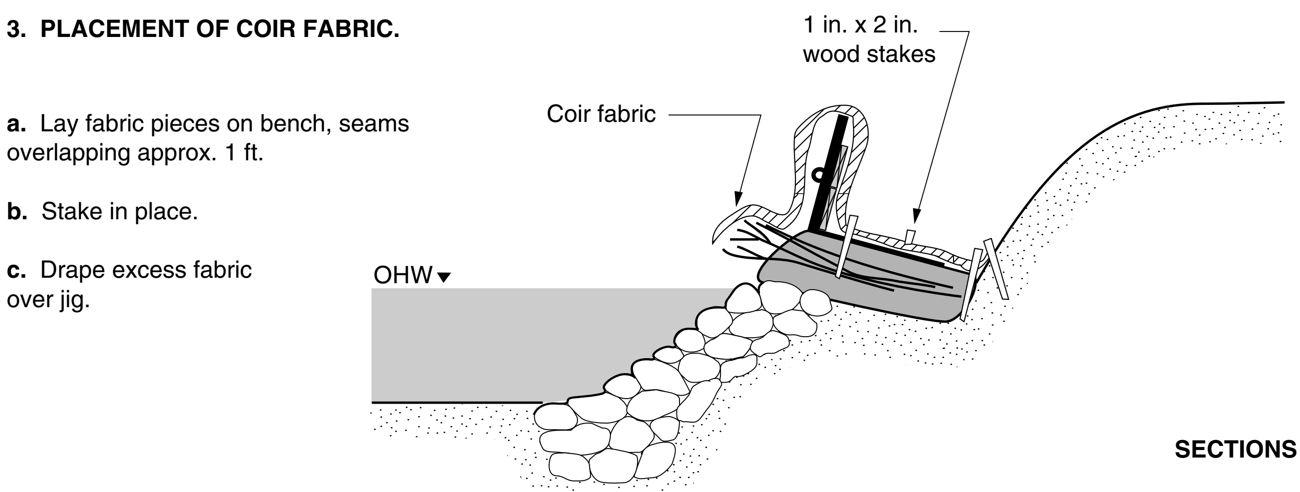


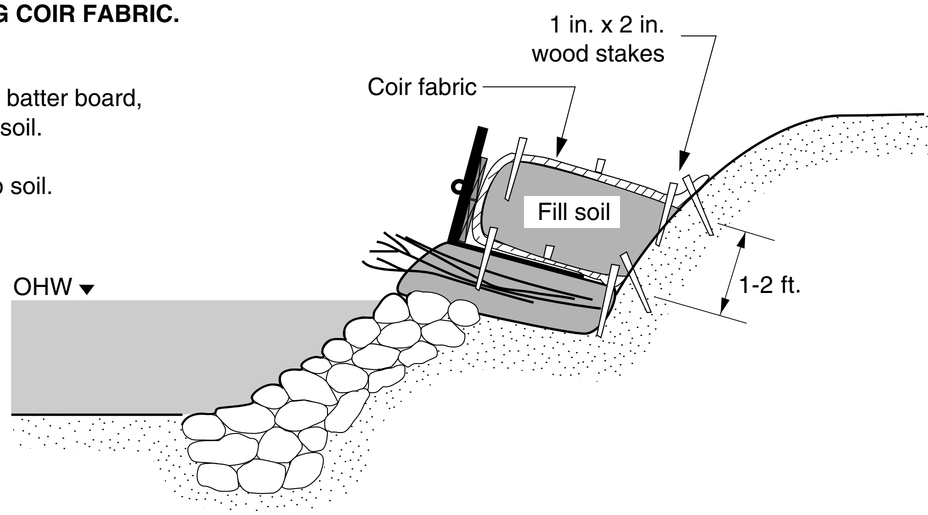
Figure 8.8 Vegetated geogrid installation using construction jigs and batter boards, continued.

4. WRAPPING AND SECURING COIR FABRIC.

a. Fill bench with soil up to top of batter board, maintaining 10-15° slope. Water soil.

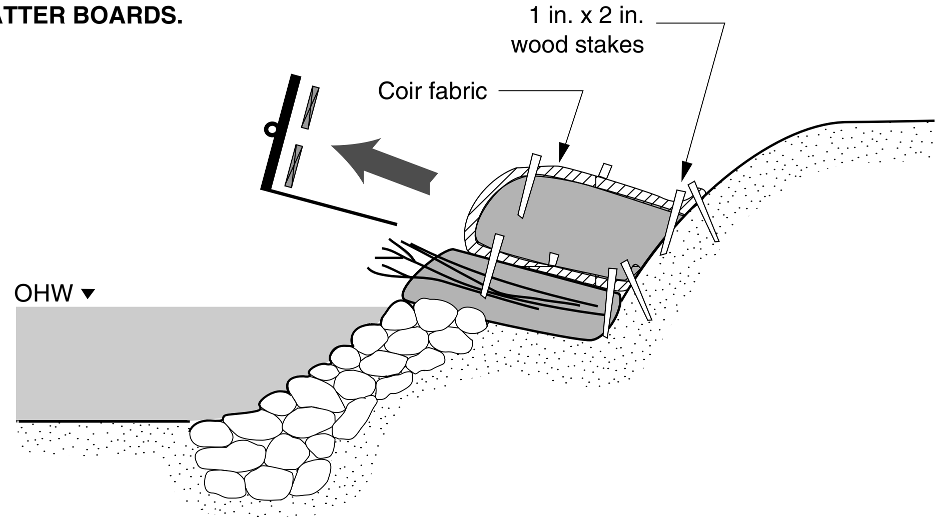
b. Pull fabric up and over to wrap soil.

c. Stake in place.



5. REMOVAL OF JIGS AND BATTER BOARDS.

Slide jigs and batter boards out.

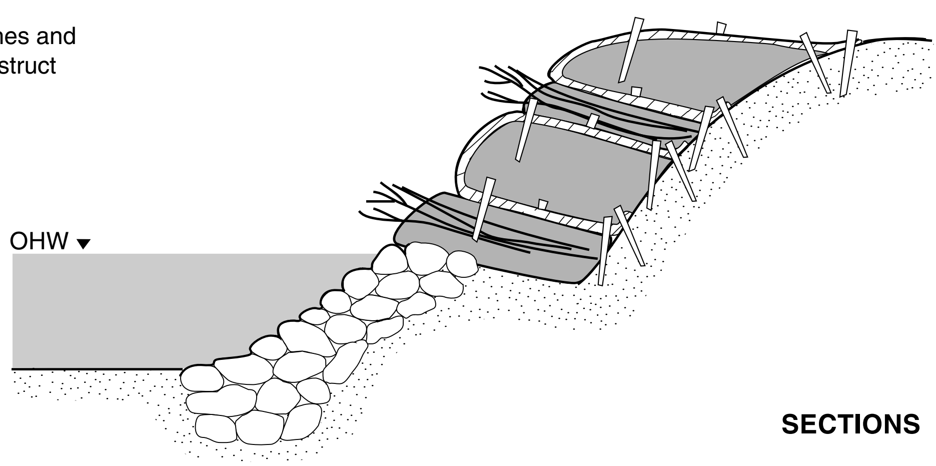


6. INSTALLATION OF ADDITIONAL GEOGRID LIFTS.

a. Lay another layer of live branches and soil on top of the geogrid and construct additional lifts.

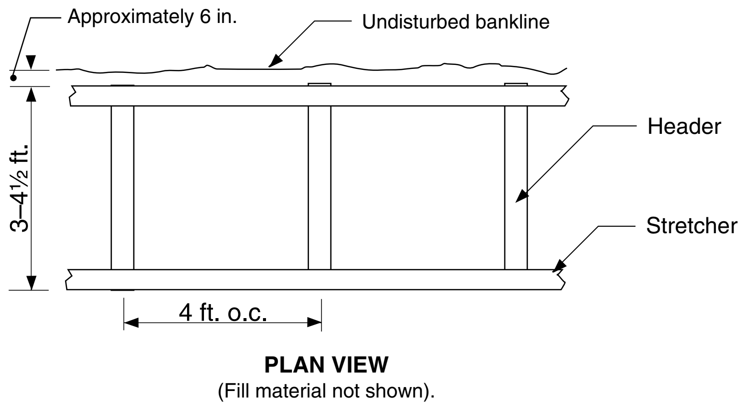
b. Seed and/or plant upper bank.

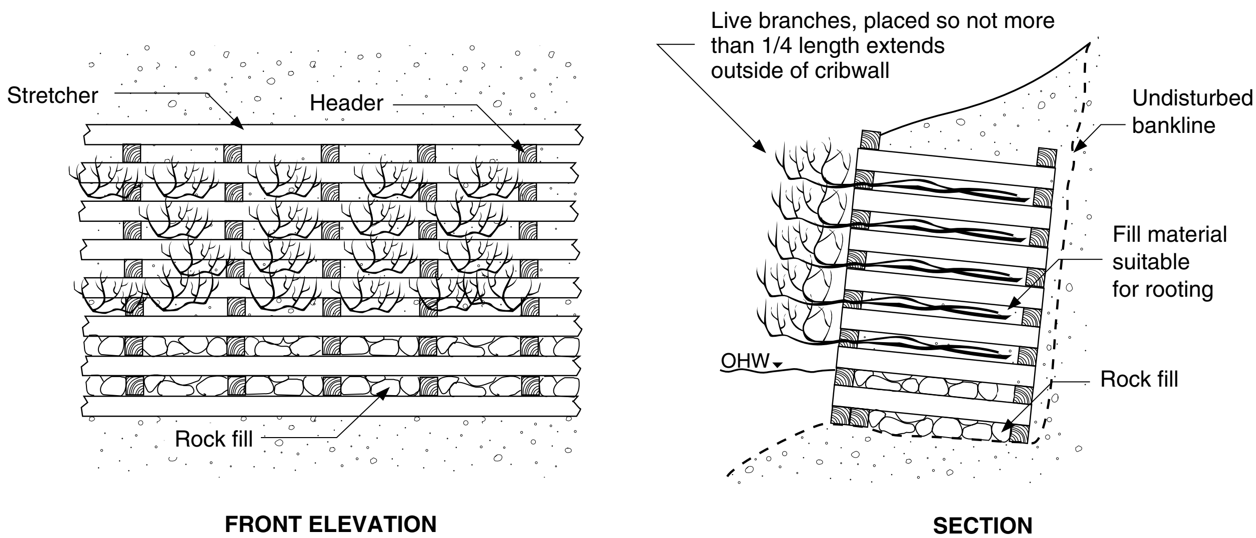
c. Water top soil of every layer.



SECTIONS

Figure 8.9 Installation of live cribwall. (Adapted from Gray and Leiser 1982.)





NOTES:

The cribwall can be constructed with either round peeled timbers or square timbers.

Fill material should be suitable for rooting, but topsoil is not necessary. Ensure even filling of soil over branches, avoiding hollow spaces.

If possible, the basal cut end of branches should extend into the soil behind the wall.

the cribwall frame (Figure 8.9). To prevent water quality degradation, cribwalls should constructed with non-treated wood. The material used to backfill the crib must include soil that will support plant growth.

Starting at the lowest point of the bank, excavate below the anticipated scour line. Construct either a rock toe or begin placing stretchers. Place stretchers (10 to 12 feet in length) 3 to 4.5 feet apart and parallel to each other. The bank stretcher should be only a few inches from the bank. If using rounded timbers, notching will increase the stability of the joints. Place the headers, typically four feet on center, on top of and perpendicular to the stretchers. Secure with rebar or spikes.

Place the initial rock fill material in the lower portion of the cribwall (up to the OHWM). Place and secure the next layer stretchers on top of the short right angle timbers. The layers should be spaced approximately the same width as the thickness of the timber. Place fill material and compact at the OHW mark so that the soil surface slopes down into the bank at least 10 degrees from horizontal. Start the first layer of live brush at the OHW mark. Arrange the branches in the open spaces between the timbers so that not more than 0.25 of their length extends beyond the face of the cribwall. If possible, the basal end of the branches should be embedded in the native soil behind the cribwall. When placing fill material over the branches, avoid creating large voids or hollow spaces; branches in these areas will not root. Continue with the logs or timbers, soil, and brush placement to the top of the live cribwall.

The branch cuttings used in constructing live cribwalls are similar to those described for brush layers. Rooted vegetation (rooted stock) may also be used.

Rocks may be necessary in front of the structure where the water velocities at the toe are expected to be very strong. Large boulders can also provide cover and refuge areas for fish.

Construction of cribwalls is discussed in detail by Gray and Leiser (1982). These authors discuss numerous cribwall designs of varying size and complexity.

Tree Revetment

To construct a tree revetment, trees are laid along the bank with the basal ends oriented upstream (Figure 8.10). They should be overlapped 0.25 to 0.33 of their length to insure continuous protection to the bank. The number of trees used depends on the length of bank to protect.

The trunks are cabled to deadman anchors in the bank, with the top of one tree overlapping and cabled to the trunk of the next tree downstream in a shingle-like effect. Piles can be used in lieu of deadman anchors, provided they can be driven well below the point of maximum bed scour. To assure proper cable tension, pull and hold the trees in against the bank while the cables are being attached. Use cable clamps to attach the cable to the trees. Cable the tip of the last tree in snugly against the bank to prevent bank scour at this location.

Do not trim branches of the trees. The use of green trees will result in less limb loss during installation. Fill large gaps between the trees and the bank with additional trees and/or rock as needed. Rocks and trees together often form a more effective structure than either alone. It is important that this type of revetment be adequately anchored to prevent trees from breaking free and damaging downstream structures.

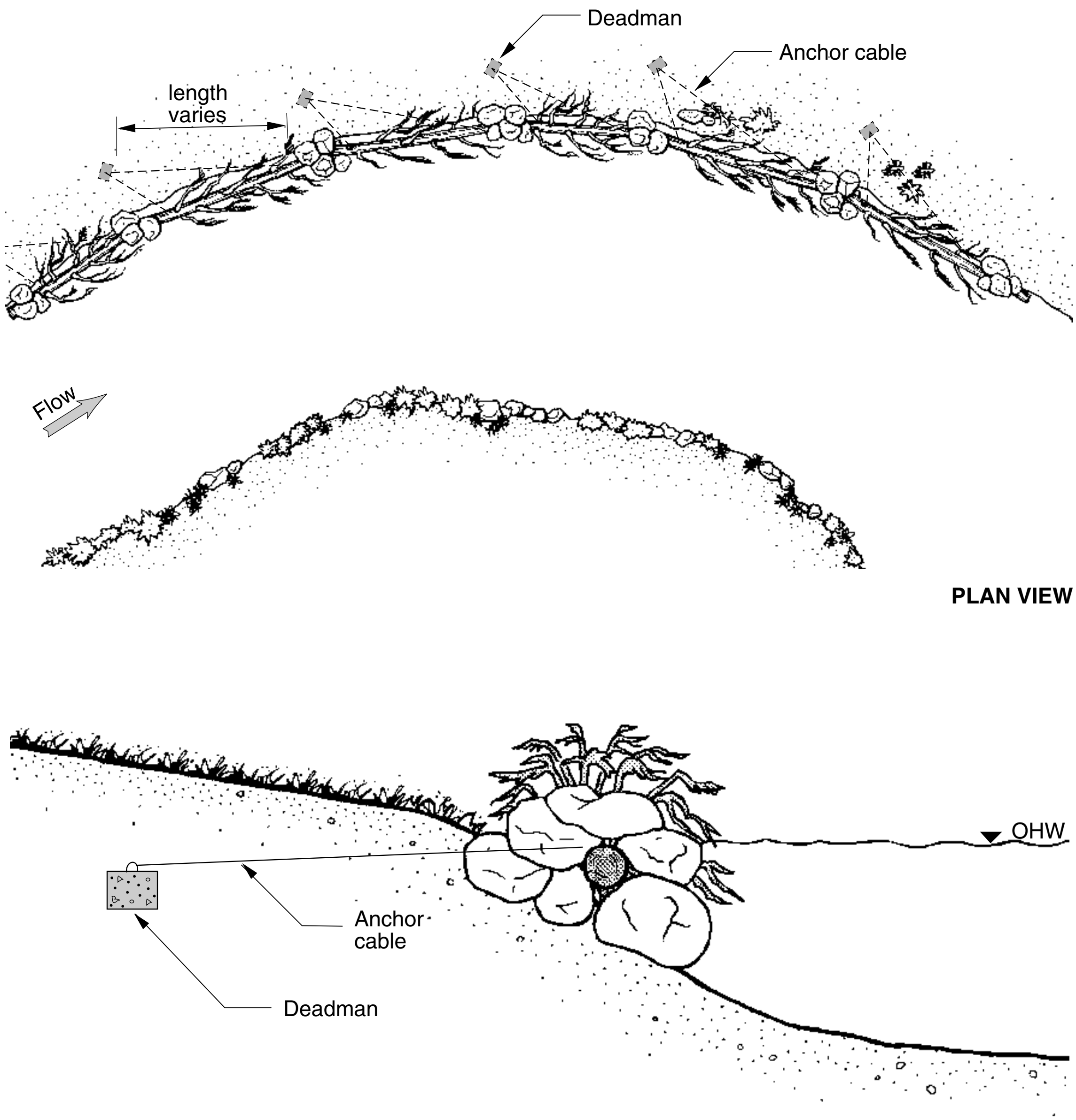
8.3.4 HABITAT COMPONENTS

Large Woody Debris

Whole trunks with roots and single logs can be firmly buried into the riverbank or bed, wedged in place with other woody elements and/or rock materials, or cabled to buried "deadman," tie-back anchors or other structures, or even living trees. Cables can also be fixed to the logs and glued with epoxies into holes drilled into large rocks. Other emplacements rely on pounding long lengths of steel reinforcing bar into underlying sediments through holes drilled through the wood pieces.

Root wads or stumps may be firmly wedged, cabled or nailed in place with rebar. Cabling can be

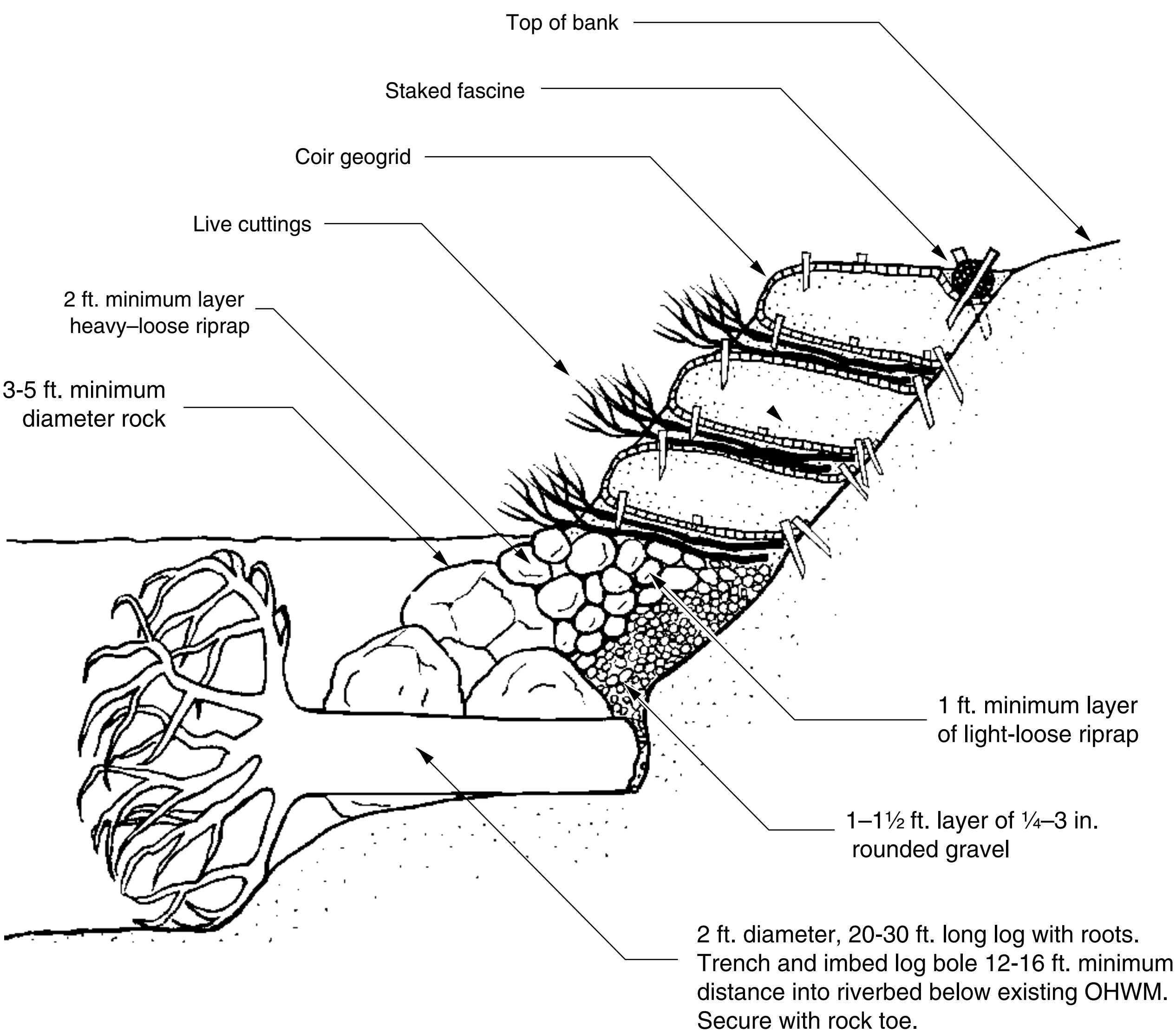
Figure 8.10 Installation of a tree revetment.



accomplished by drilling through the root and/or stump portion, passing a cable through the hole, and cementing each end of the cable to a large rock. A variation is to swage (i.e., crimp) a ferrule (i.e., bushing) around the cable; the free end is passed through a hole drilled through the center of the root and up through the center of the tree rings. The cable is then epoxied into a large boulder. If cabled, precautions should be taken to minimize possible movement or shifting of these devices. Project designers should also be aware that each piece of wire rope introduced into the river system is a potential hazard to swimmers, boaters, rafters, and wildlife.

In large river systems such as the Green or Cedar Rivers, secure large woody debris (preferably 20 feet long or more and 20 inch minimum diameter) by burying them directly into the rock toe buttress (Figure 8.11) (A. Levesque, King County SWMD, pers. comm., 1992). Where facility reconstruction will allow, this can occur without further excavation into the bankline. In other cases, especially where setback modifications to the facility alignment are proposed, a trench may be required to embed the top of the log partially into the bankline itself. In both cases, the logs should be secured firmly in place with large rock (three to five foot minimum diameter rock), with a minimum of four to five rocks placed along its length. Smaller stone and granular materials may be needed to fully embed the log in fine-grained bed or bank excavation materials. The root end of the log should protrude from five to eight feet beyond the edge of the rock installation, at a 30 to

Figure 8.11 Integrated system using large woody debris.



45 degree angle to the bankline and at 2 to 20 degrees downward towards the streambed. The entire log should be placed below OHW to keep it fully saturated at lower flows. It is recommended that layers of woody vegetative cuttings and topsoil be placed directly over the full dimension of the log and rock emplacement. The vegetation should be deeply rooting and tolerant of saturated soils.

Fishrocks

The proper rock position in the flow depends upon its shape, the angle at which the flow hits the rock, and the site objectives. Place rocks such that, at bankfull discharge, the flow is deflected toward the area where the scour is desired. Orsborn and Bumstead (1986) recommend placing the long axis of the rock parallel to the flow. This orientation reduces the chance of the boulder tipping into its scour hole and is less likely to direct the flow into the bank. To ensure the stability of rocks, align them with the flow so that the flow will not rotate them.

Avoid placing rocks so that flow is directed into erodible banks (Wesche 1985). Before installing, examine the stability of a fishrock from three perspectives. First, the shape and orientation of the rock will have an impact upon the depth and volume of scour. Second, expect upstream rotation of the fishrock as most undercutting will occur on the upstream face of the rock. Under high velocities, the fishrock may become cantilevered and tip into the scour hole it has created. Finally, expect an elongated rock to naturally shift its major axis at least 45 degrees to the flow. Plan for this and initially install elongated rocks approximately parallel to the flow since this orientation is more naturally stable.

Whenever possible, use equipment stationed on the bank to place rock. In larger rivers, installation of fish rocks may require operation of equipment instream.

8.4 CONSTRUCTION INSPECTION AND SITE CLEANUP

Site inspection and construction monitoring must occur during project installation to ensure that the design specifications are met. While facilities can be adequately designed, projects will not be successful if construction materials do not meet the required specifications or if the materials were installed improperly. Many of the items listed in Section 8.1 are activities that occur throughout construction of the project. At the close of construction, the project supervisor should ensure that all elements of the design have been installed according to specifications. Any changes to the design specifications should be documented as revisions to the final design drawings to reflect the as-built condition of the project.

At the end of each work day, construction sites, especially in residential areas, should have construction debris, plant materials, soil, tools, and other material picked up from roads and other areas. The site should be left as neat as possible and practical every day. During the day, vehicles and equipment not in use should be stored out of the way of local residents or businesses. These measures help maintain friendly relations with people inconvenienced by the presence of equipment and work crews.

Advance planning and organization of the work site also eliminates rearrangement of stockpiled materials. Items should be kept readily available, but not in the way of workers or equipment. The area immediately adjacent to the streambank usually must be kept clear to allow equipment access where it is needed. When several stabilization components will be used, areas should be identified for these specific materials so that the quantities available can be determined quickly and clean-up is organized. It is preferable not to store cut plant material overnight; if it must be, provide an area where the stems can be covered with moist (not wet) soil or stored with the basal ends in the stream.

At the completion of a project, staging areas should be restored to preconstruction conditions. Remove unneeded or scrap material that could endanger wildlife or enter the stream, and repair damage to property, landscaping, lawns, and driveways caused by the work. Grade and reseed disturbed lawns or areas that may be subject to surface erosion.

If possible, return plant containers to the nursery or to a recycling or redistribution center. Many nurseries give cash or credit towards future purchases for returned plant containers. Clean Washington Center (206-464-7040) and the Industrial Materials Exchange (IMEX) (206-296-4899) are two organizations involved in waste reduction and who can provide information on how to acquire or dispose of many recyclable and reusable products. This includes landscaping materials such as commercial compost and plant pots.

RECOMMENDED SOURCES FOR ADDITIONAL INFORMATION

Coppin, N.J. and I.G. Richards. 1990. Use of Vegetation in Civil Engineering. London, England.

Gray, D.H. and A.T. Leiser. 1982. Biotechnical Slope Protection and Erosion Control. Van Nostrand Reinhold Company. New York, N.Y.

Schiechtl, H. 1980. Bioengineering for Land Reclamation and Conservation. University of Alberta Press. Edmonton.